

Using HyTrans to Study H2 Transition Scenarios

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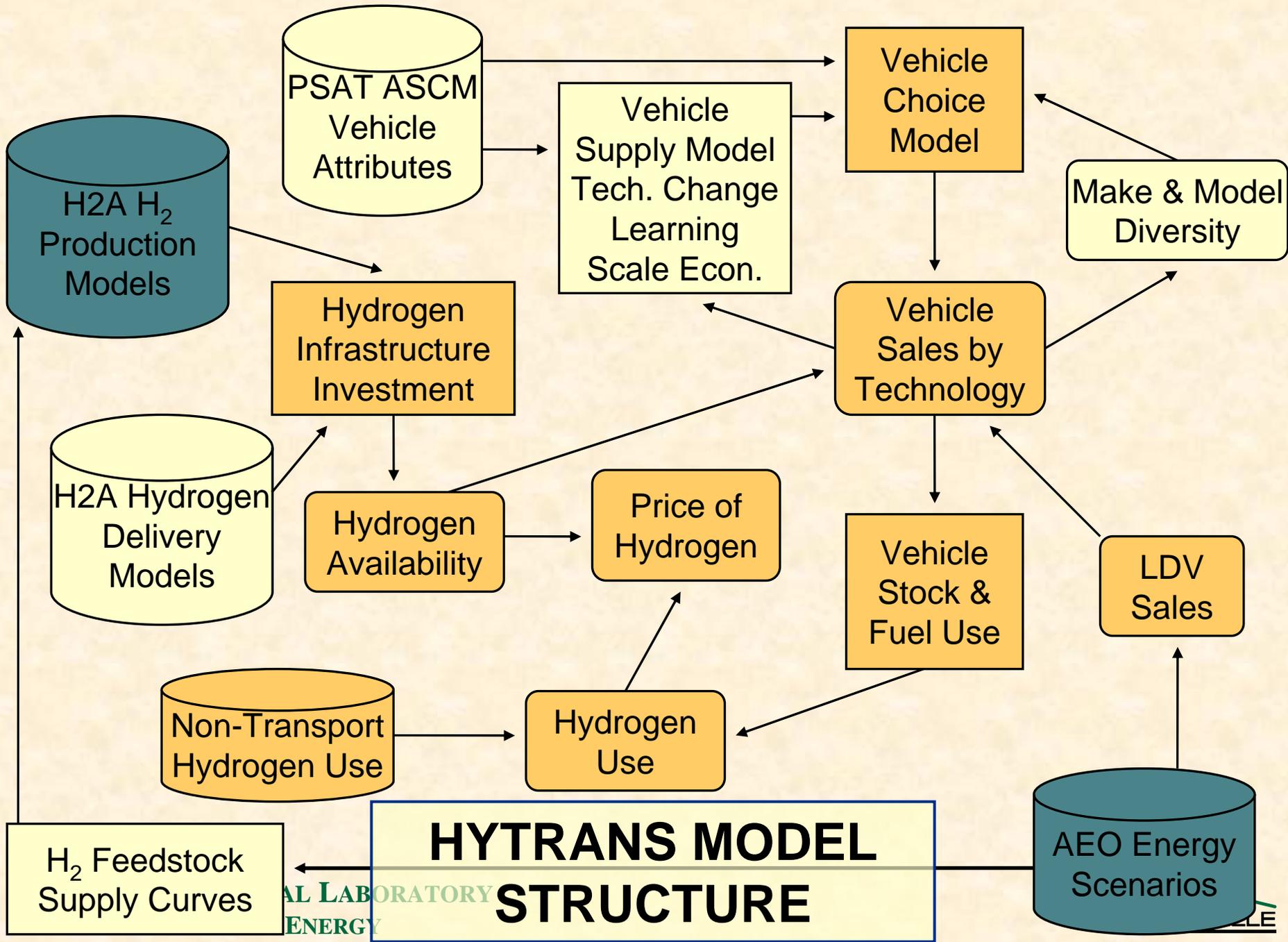
We will try to cover 4 topics in ½ hour because what we want is your input.

- 1. What is HyTrans?**
- 2. What can it do?**
 - 1. Previous analyses**
 - 2. Initial early transition runs**
- 3. What improvements are needed for realistic early transition analysis?**
- 4. How will we interface with NREL's detailed GIS analyses?**

1. What is HyTrans?

HyTrans is a national (regional) model of the market transition to a H₂ vehicle system designed to be useful for R&D planning, cost-benefit analysis, policy analysis and envisioning.

- **Integrates all main H₂ market components**
 - Hydrogen Production
 - Hydrogen Delivery
 - Vehicle Production
 - Consumer Choice
 - Hydrogen Use
- **Determines a market equilibrium solution**
 - Maximizes total consumption benefit minus production, distribution, and other costs
 - Estimates amounts and timing of costs, benefits, levels of investment and activity, production and consumption, key environmental impacts.
 - Sensitive to technological goals and supporting policies.



A H2 Supply Pathway comprises three parts.

Delivery

Compression/Liquefaction+ Storage
+Dispensing+Transporting+ Storage
+Compression/Vaporization

Production

Centralized SMR
Coal Gasification
Biomass, etc.

Forecourt (Store + Dispense)

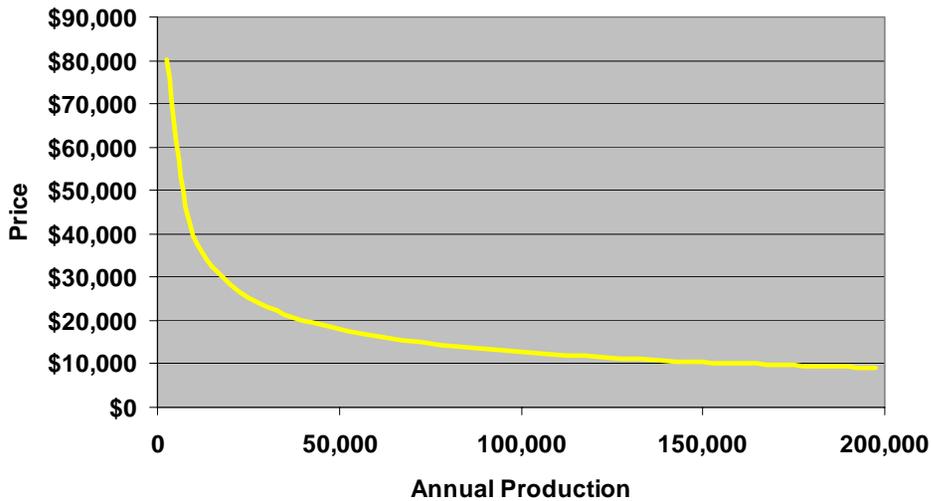
Retailing of
Compressed
Gas

Forecourt SMR
Forecourt Electrolysis
Many Others...

HyTrans includes a wide range of H production technologies (current and future) based on two major studies (NAS & H2A).

Production Technologies	NAS		H2A		
	Current	Future	2005	2015	2030
Central					
SMR with CO2 Capture	X	X	X	X	X
SMR without CO2 Capture	X	X	X	X	X
Central Electrolysis	X	X			
Central Wind Electrolysis			X	X	X
Central Wind Electrolysis plus power			X	X	X
Coal Gasification with CO2 Capture	X	X	X	X	X
Coal Gasification without CO2 Capture	X	X	X	X	X
Biomass gasification without CO2 Capture	X	X	X	X	X
Biomass gasification with CO2 Capture	X	X			
Advanced Nuclear Energy – HTGR and High Temperature (Steam) Electrolysis					X
Advanced Nuclear Energy - ALWR/Conventional High Pressure Electrolysis				X	
Advanced Nuclear Energy – HTGR with Sulfur Iodine Thermochemical Process					X
Forecourt					
SMR	X	X	X	X	X
Electrolysis	X	X	X	X	X
Ethanol Reforming			X	X	X
Wind Electrolysis	X	X			
Solar Electrolysis	X	X			
Hybrid Wind Electrolysis	X	X			
Grid Electrolysis	X	X			
Hybrid PV, and Grid Electrolysis	X	X			
SMR SOX future		X			

Scale Economies with Elasticity of -0.5

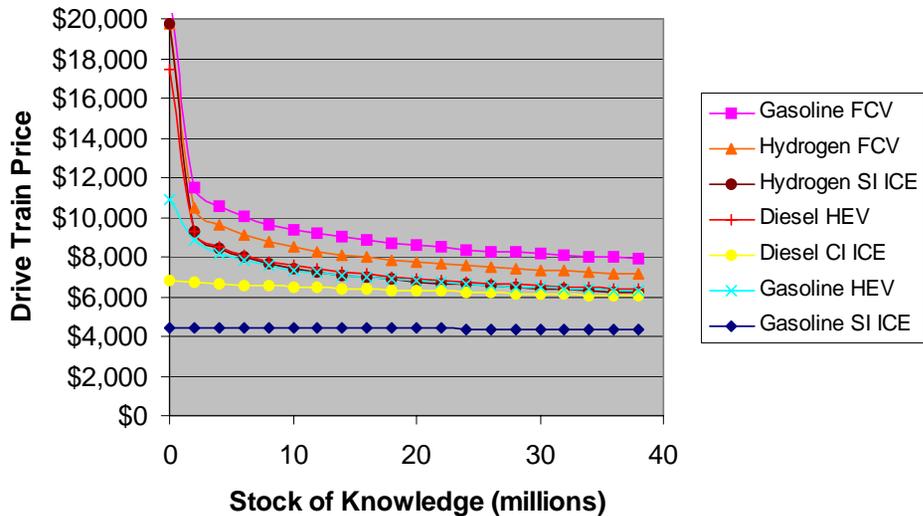


Vehicle technologies improve by 3 mechanisms.

$$\text{Retail Price} = \text{Scale} \times \text{Learning} \times \text{Tech Change} \times \text{Scenario Price}$$

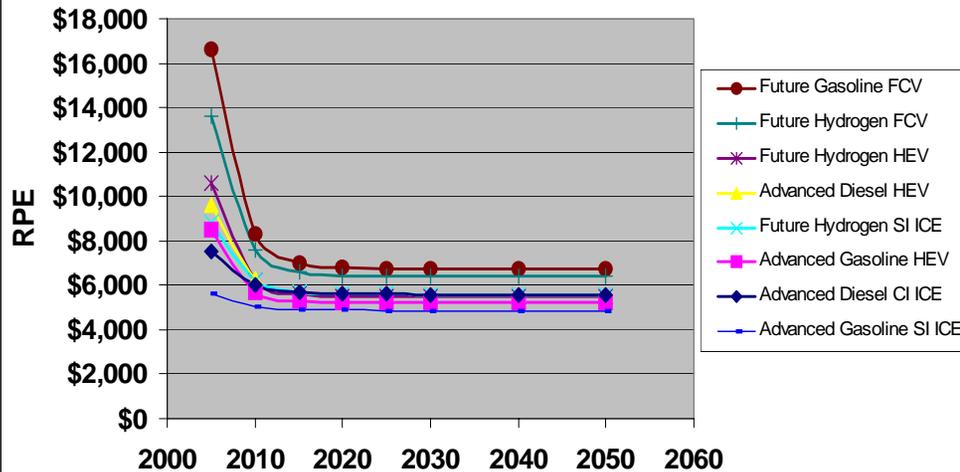
Scale w/ Annual Production/Plant

Asymptotic Learning Model



Effect of Technological Change on Incremental Prices Advanced Vehicle Technologies

DOE Freedom Car Goals Scenario

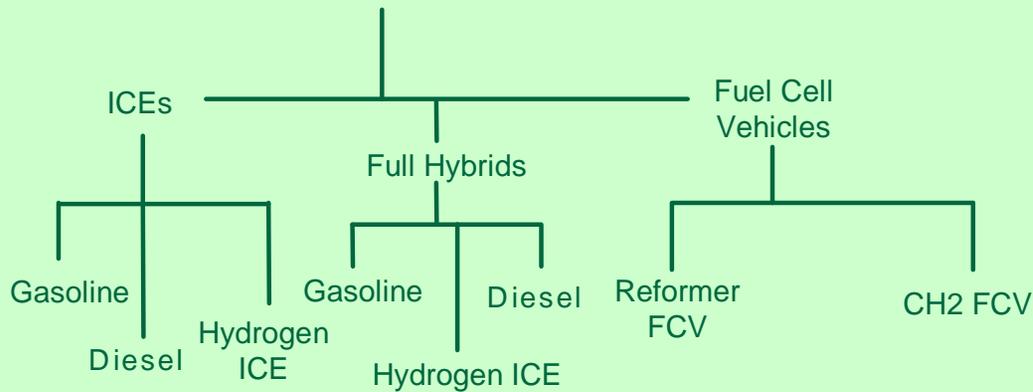


Learning & Unlearning w/ Stock on Road

Tech Change w/ Passage of Time (Yr)

Consumers' choices of vehicle technology are represented by a Nested MNL vehicle choice model that predicts the market shares of alternative technologies (grouped into "nests" of closer substitutes) based on their attributes.

Light-duty Vehicles Sales



HyTrans' vehicle choice model includes most variables the NAS (2004) report listed as important.

	NAS 2004	HyTrans
Retail Price	X	X
Operating (fuel) cost	X	X
Maintenance cost	X	X
Range	X	X
Passenger/cargo space	X	Cargo
Performance (accel. +)	X	Accel
Quality	X	No
Safety	X	No
Battery cost	No	X
Value of electricity generation	No	X
Extra value of fuel cell vehicle	No	X

The US (& region 9) is divided into 3 fuel demand density regions. The delivered cost of hydrogen depends on density.

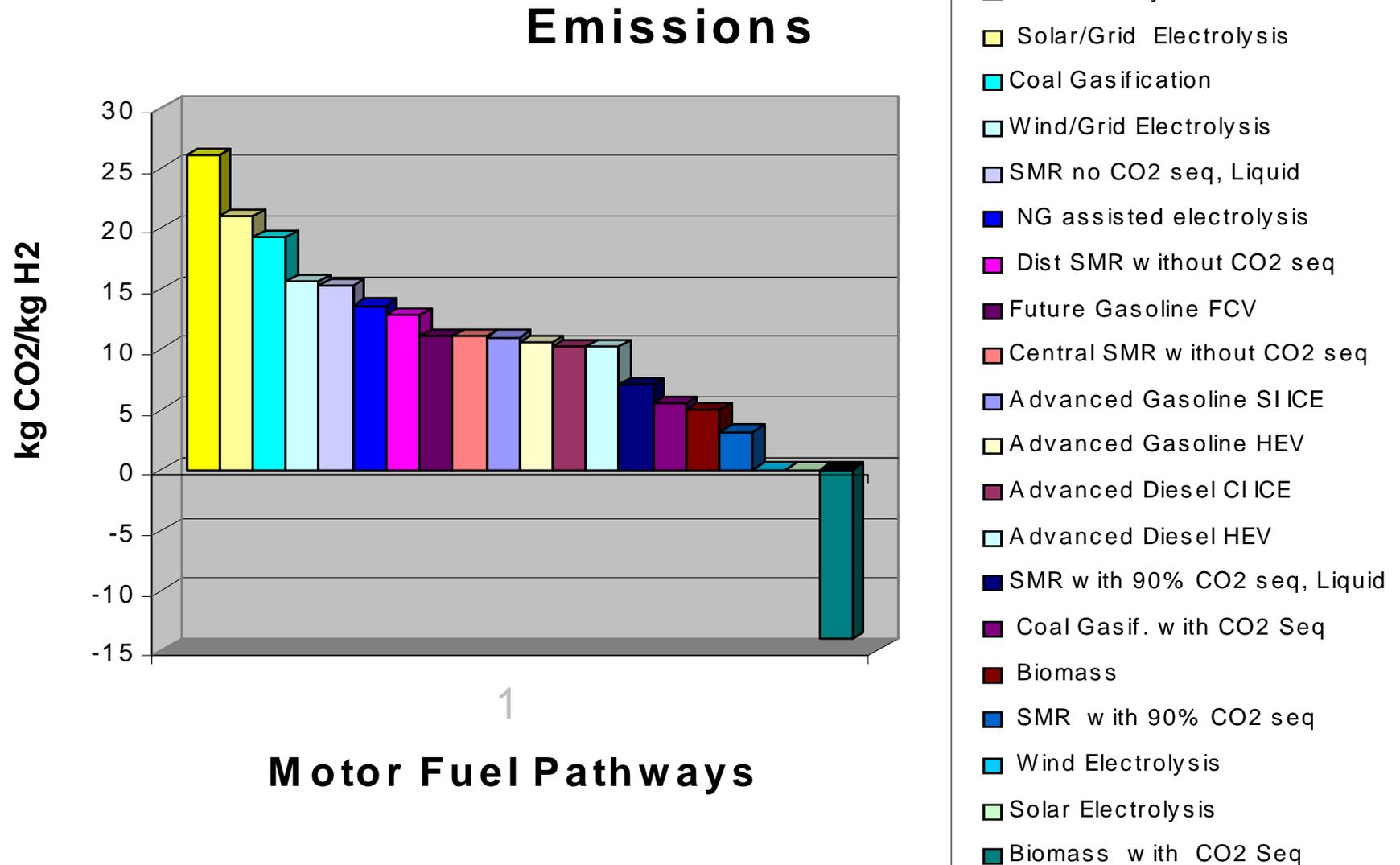


According to EPA data, 2/3 of LDV fuel is used in <10% of the land area.

The two high fuel demand density areas in Region 9 are LA and the Bay Area (>240,000 kg/km²/year).



HyTrans includes GHG emissions estimates obtained from the ANL GREET Model.



2a. What can it do?

Previous analyses.

What kinds of questions can HyTrans answer?

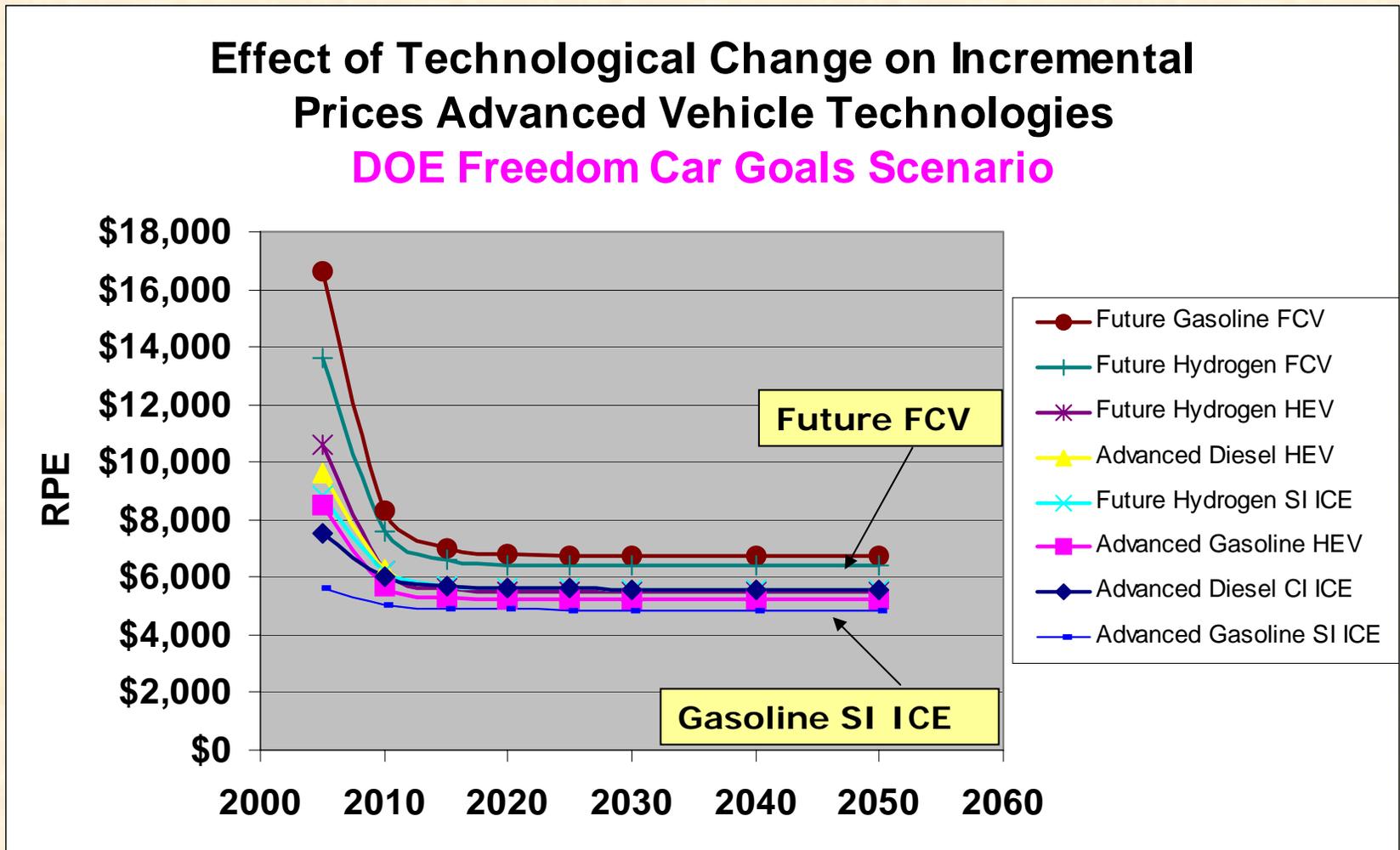
- **Produces plausible answers to key issues:**
 - Is a stable transition achievable?
 - When?
 - How long will it take?
- **Can test effectiveness of alternative policies**
 - Vehicle or fuel subsidies or tax policies
 - Mandates or regulatory policies
 - Demonstration fleets, etc.
- **Produces cost and benefit measures**
- **Close to creating useful visions of the transition**
- **Beginning to generate insights about R&D goals**
 - Good enough for a stable transition?
 - Effects of competing technologies?

We have used HyTrans' to produce several provisional transition scenarios and tested its sensitivity to key assumptions and parameters.

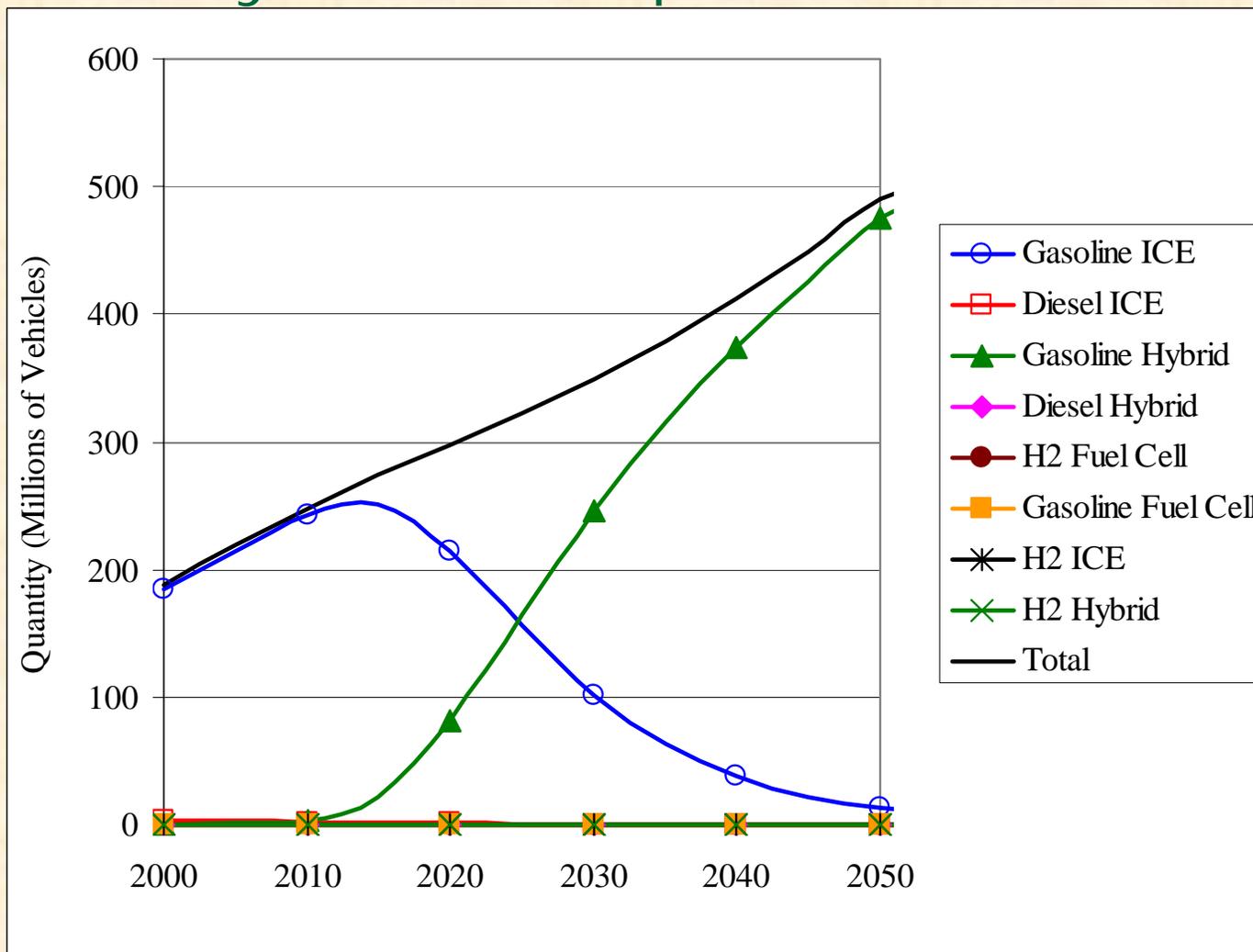
- **Base Case (NAS, FreedomCAR technologies)**
- **Vehicle technology evolution**
- **H2A v. NAS**
- **Energy Prices**
- **Feedstock Supply Curves**
- **Societal Discount Rate**
- **Scale Economies in Vehicle Production**
- **Consumer Choice**
 - Price elasticities
 - Cost of low fuel availability
- **GREET CO₂ coefficients & Low C constraints**

SCENARIO 1

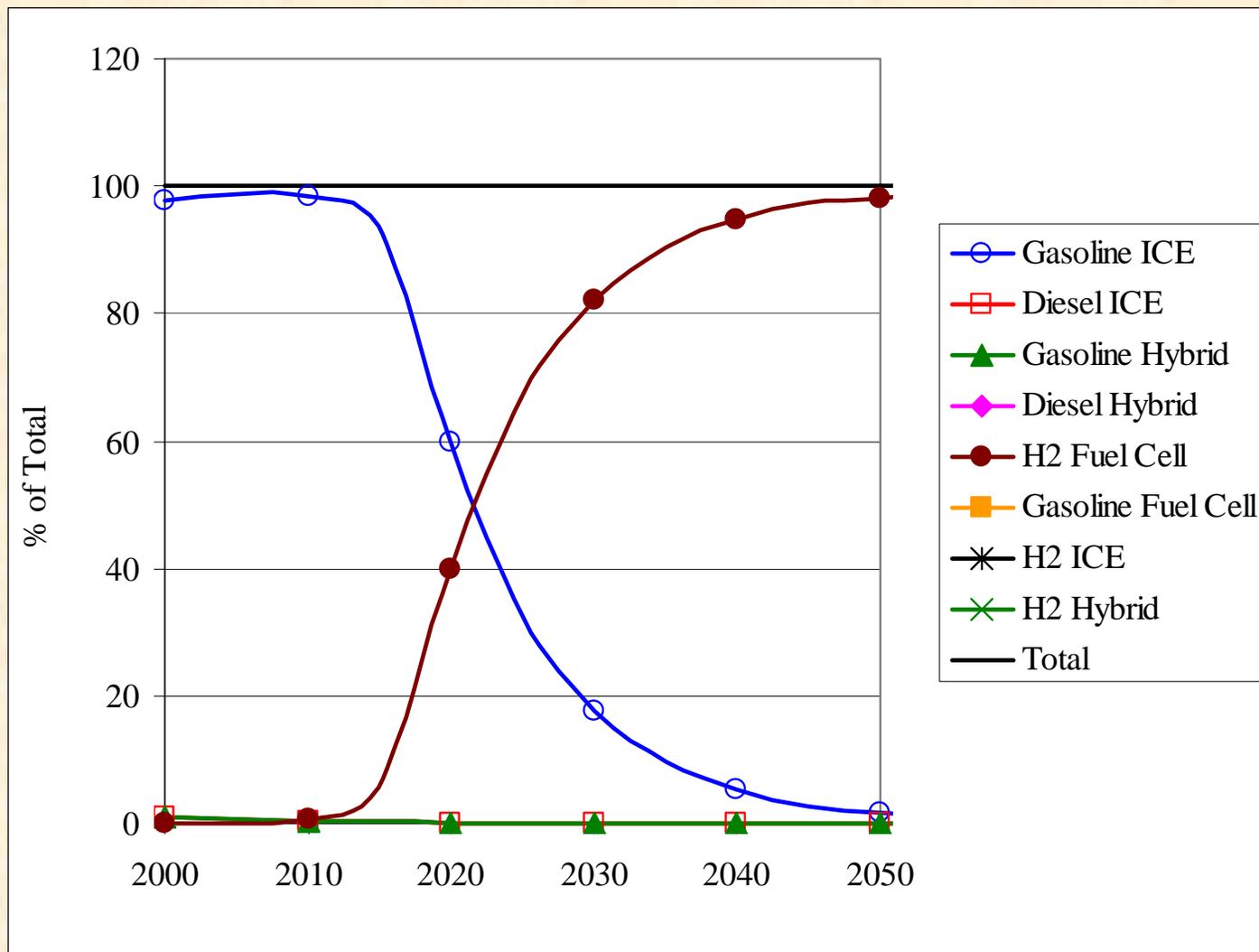
The DOE Vehicle Technology Program Goals scenario anticipates rapid progress for all technologies.



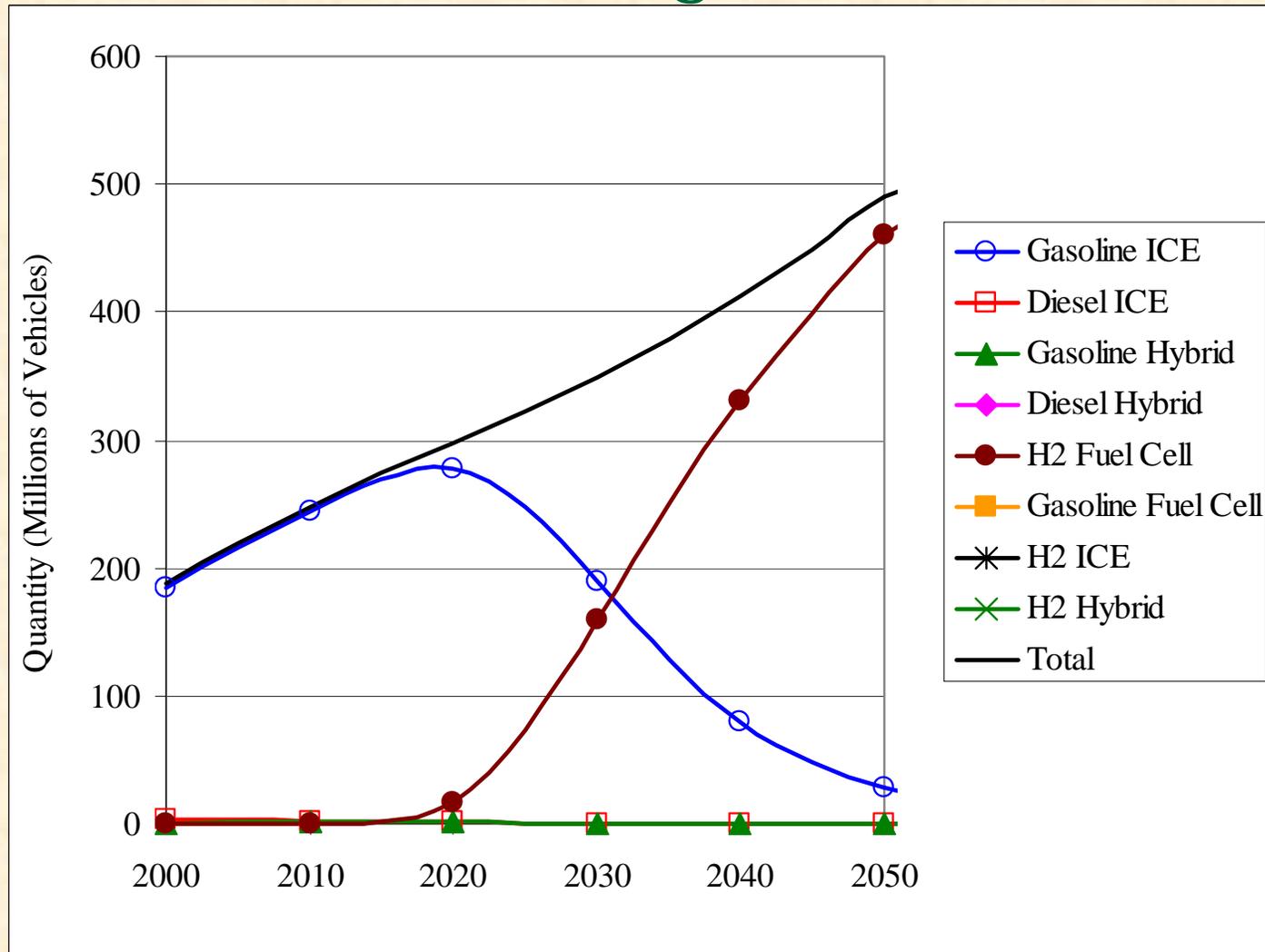
In the Base Case with no new policies gasoline hybrids conquer the market.



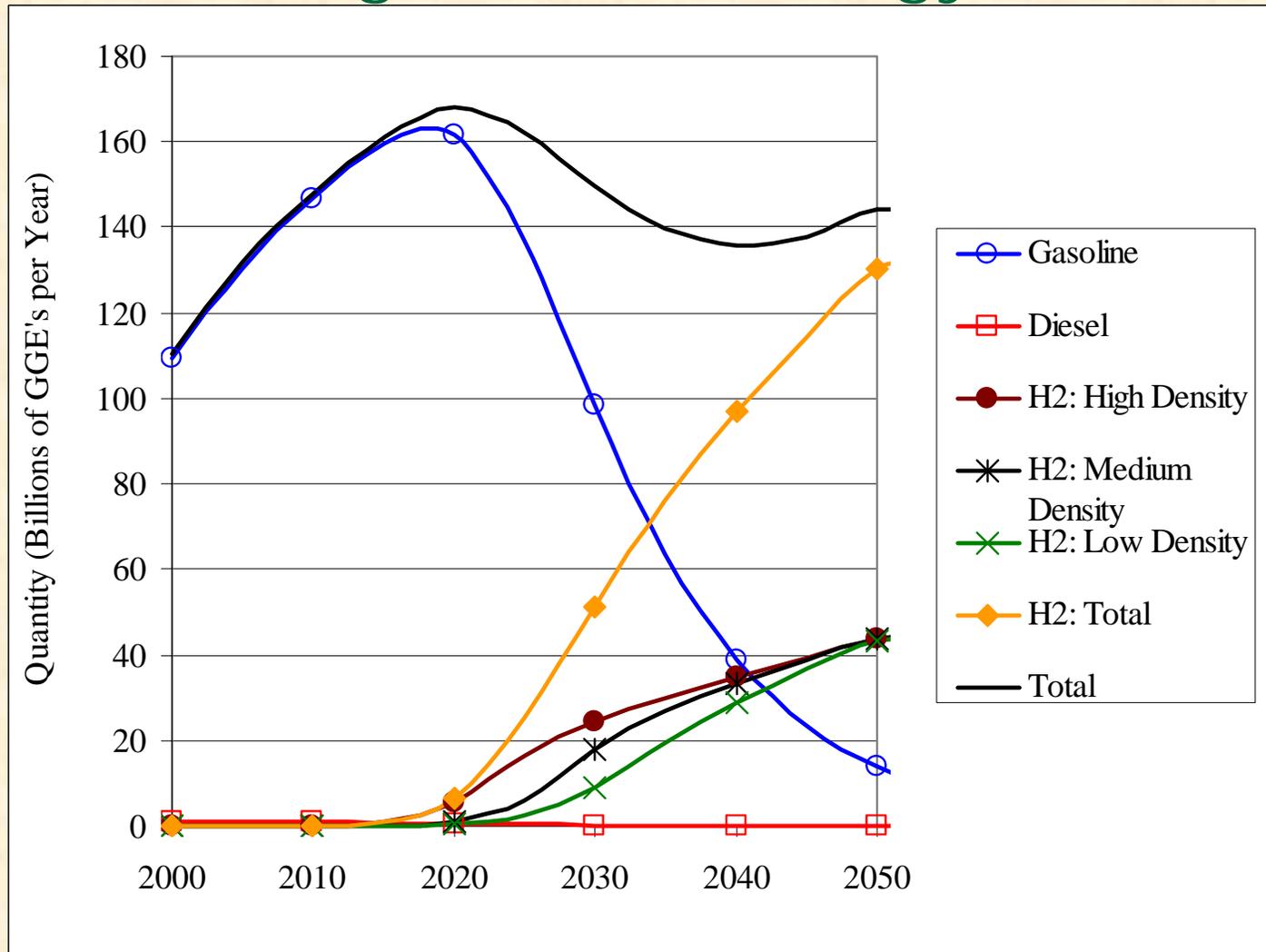
A \$1,500/vehicle subsidy (discontinued in 2030) brings on FCVs instead of hybrids, 5 years later.



It takes 30 years for hydrogen FCVs to replace conventional gasoline vehicles.

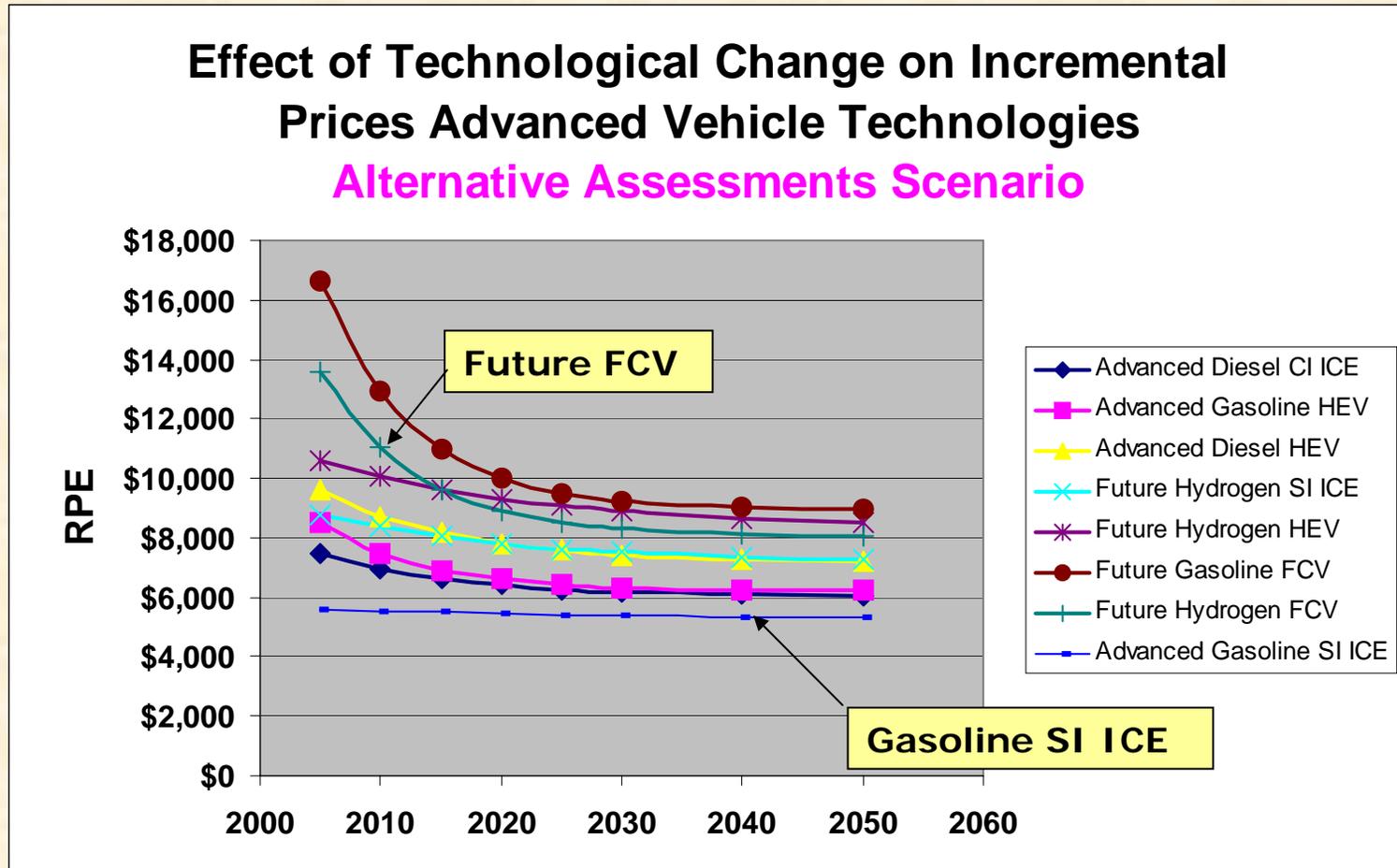


The greater efficiency of FCVs actually reverses the growth of energy demand.

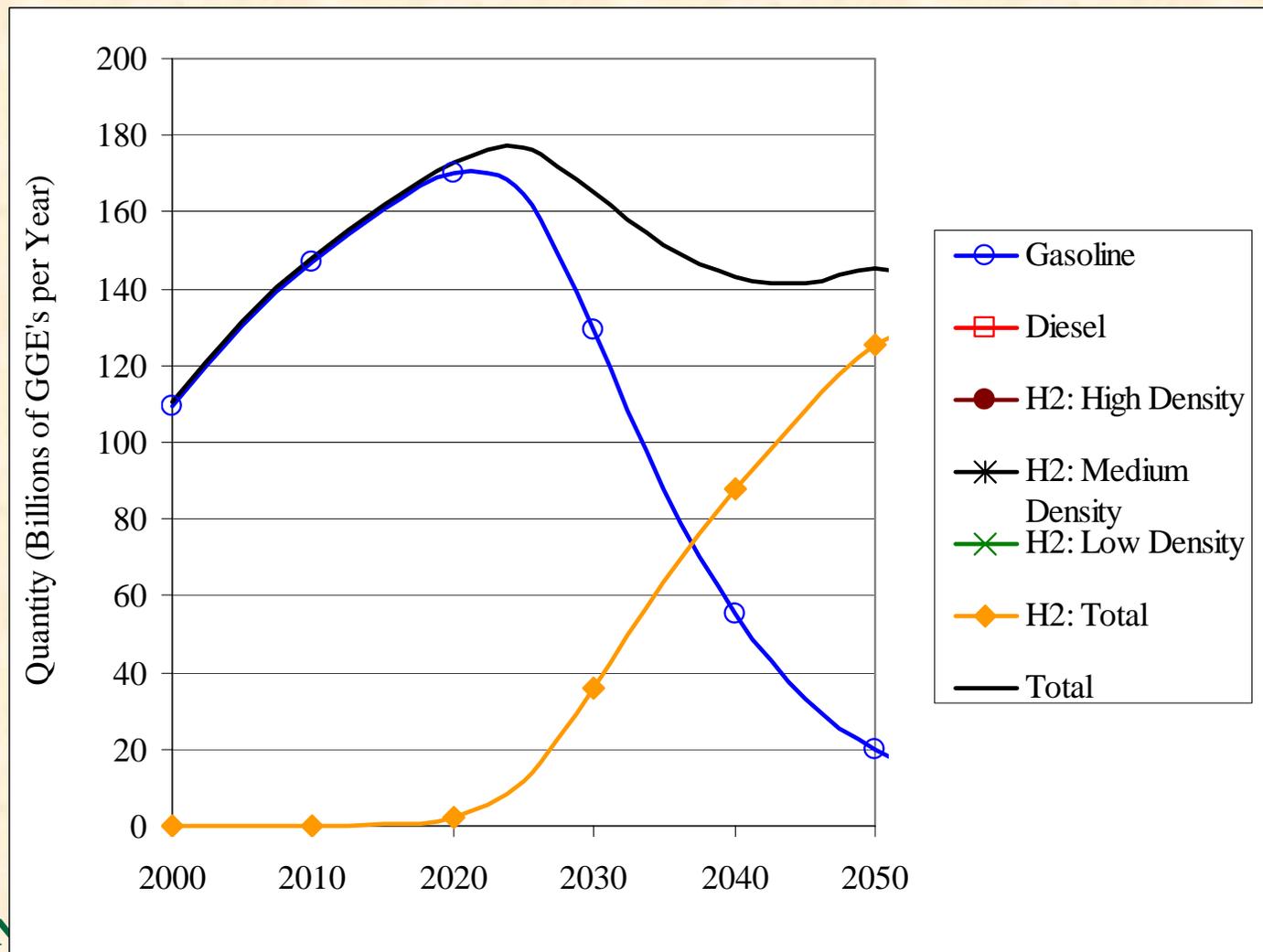


SCENARIO 2

We derived the Alternative Vehicle Technology Case from published studies. It is less favorable for some technologies, certainly for FCVs.

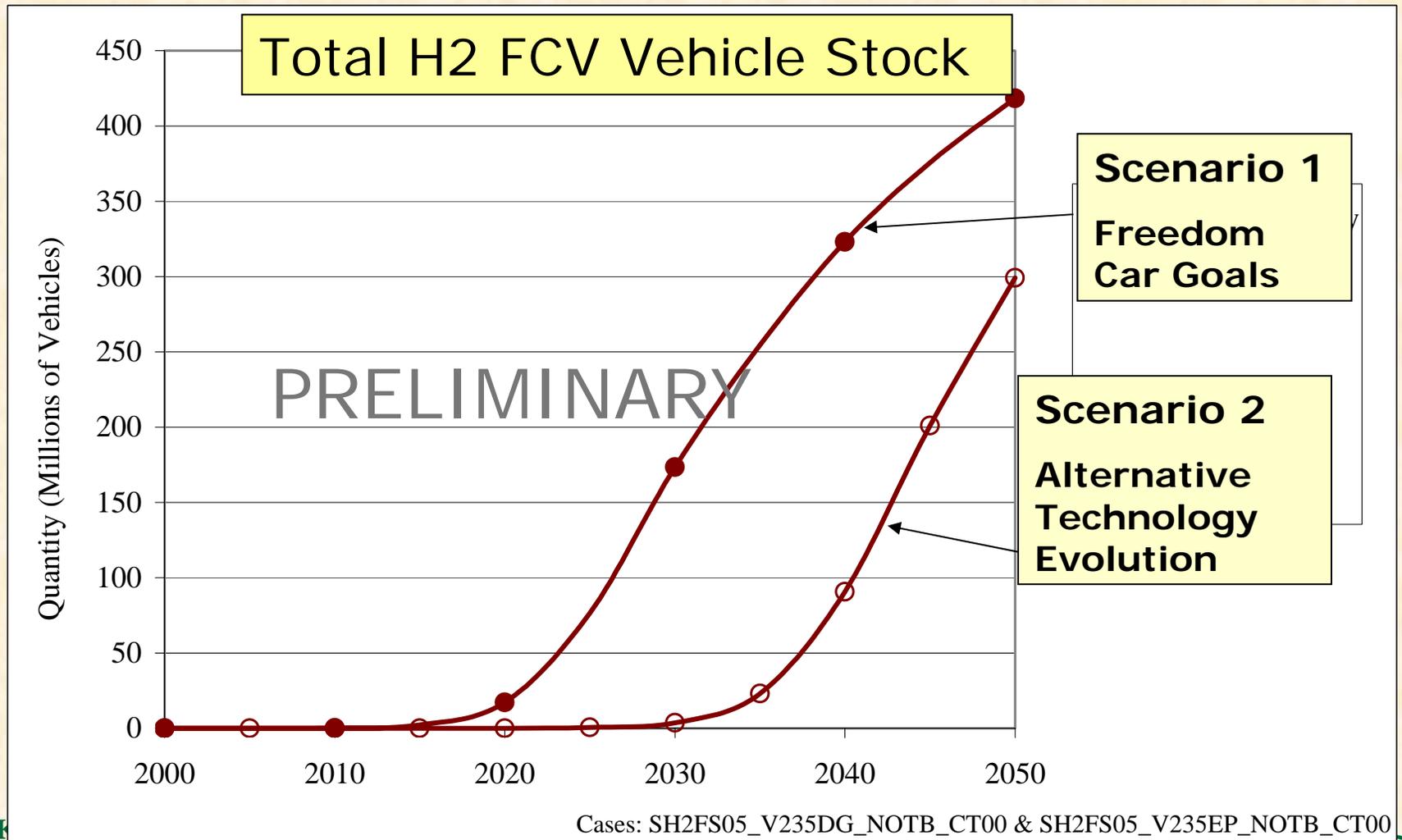


In the alternative technology case it took a \$3,000 subsidy (discontinued in 2030) to cause a transition to FCVs.

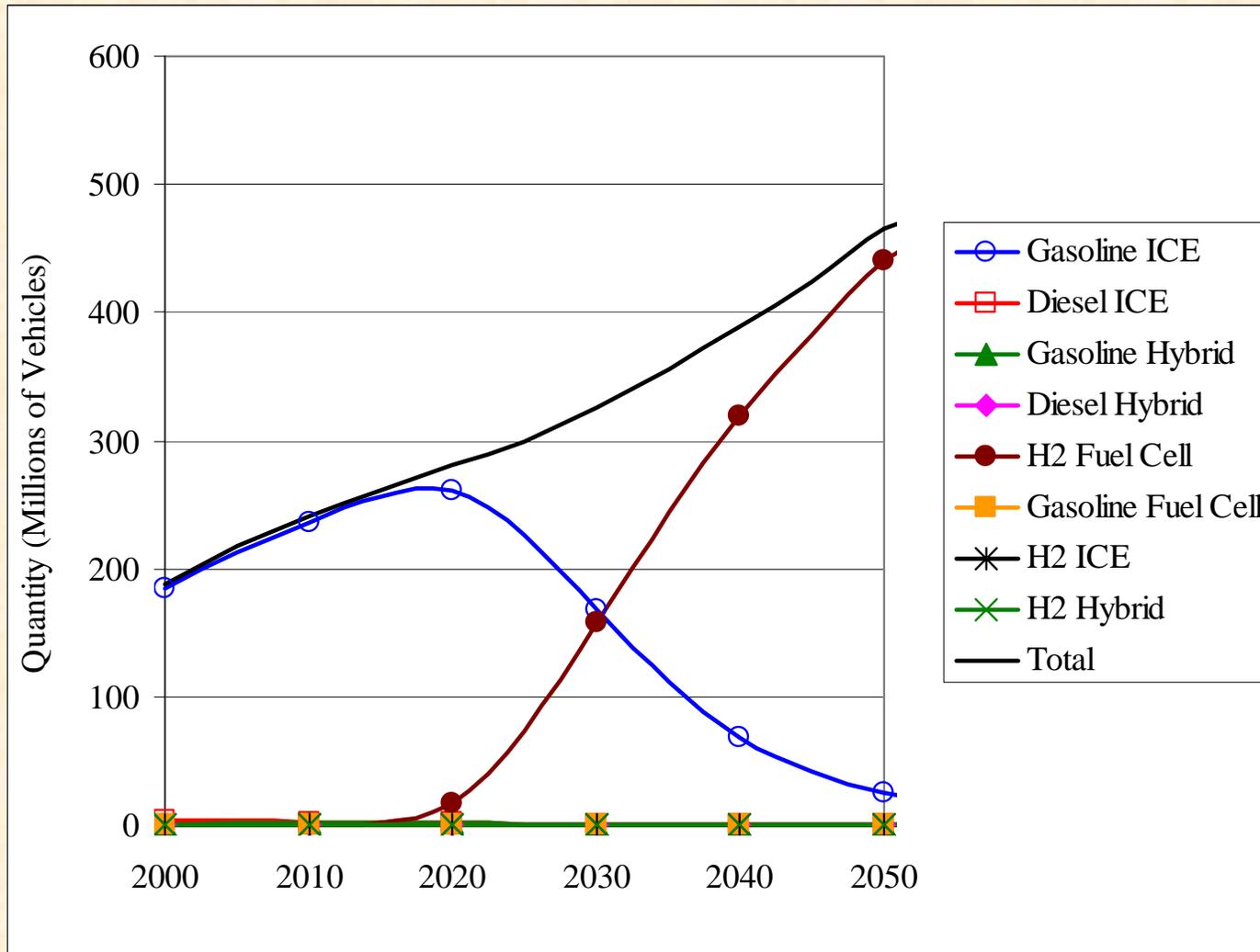


Given the same fuel subsidy policy, the H2 transition occurs later in scenario 2.

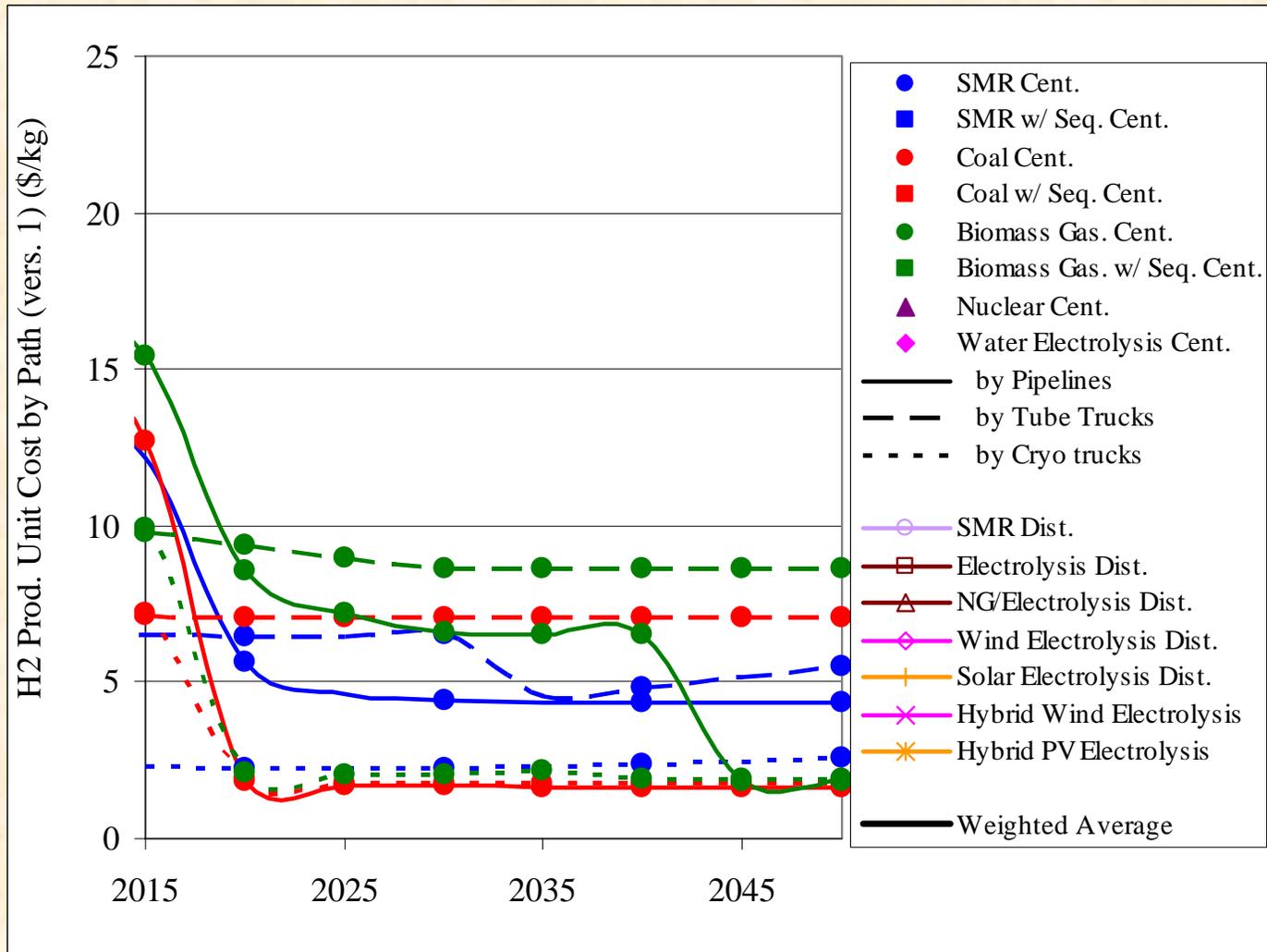
(Scenarios 1 & 2: \$0.90/GGE H2 Fuel Subsidy)



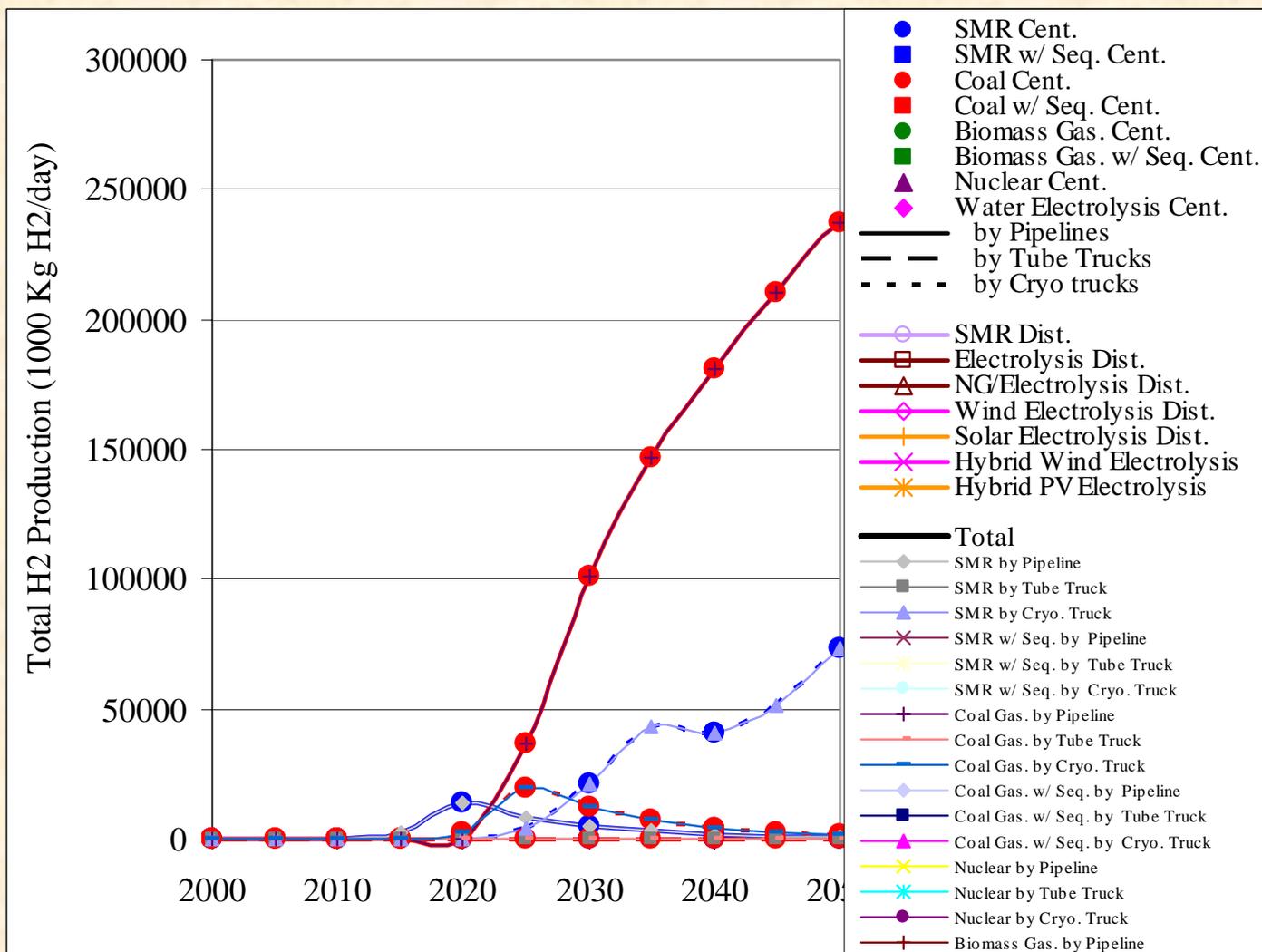
With higher oil prices (\$48 v. 30\$/bbl in 2030) a \$1,000 is sufficient to cause the transition to H₂.



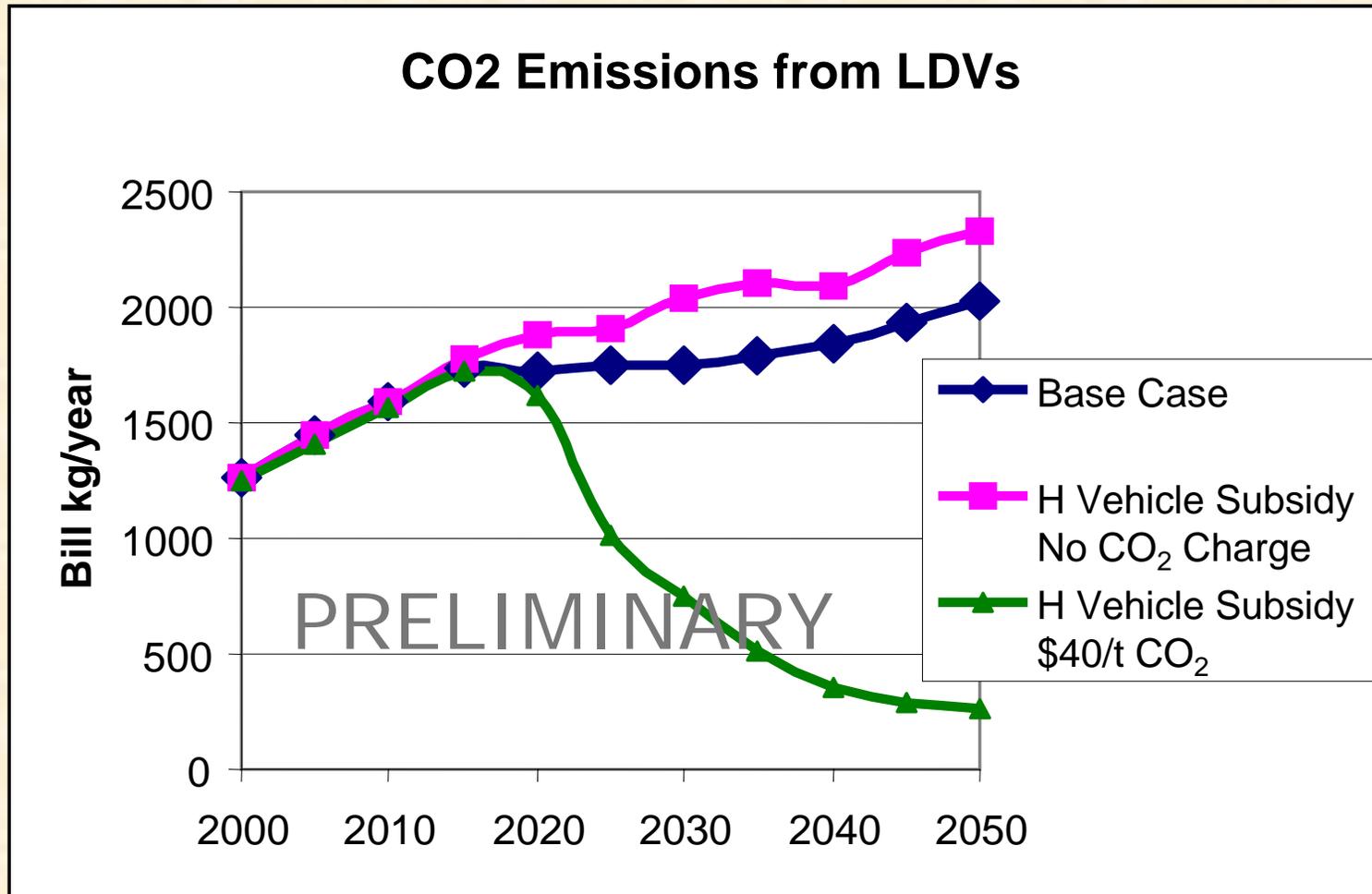
According to H2A, Coal, SMR and biomass can be produced at comparable prices.



Introducing feedstock supply curves raises the cost of hydrogen and the required subsidy for a transition, but also diversifies the hydrogen supply system.



Transition to H₂ creates an opportunity for massive reductions in C emissions.



2b. What can it do?

Initial Early Transition Scenarios

1. Added Census Region 9
2. Added existing H2 supply
3. Ran 4 transition scenarios

Realistic transition scenarios is our goal for FY 2006.

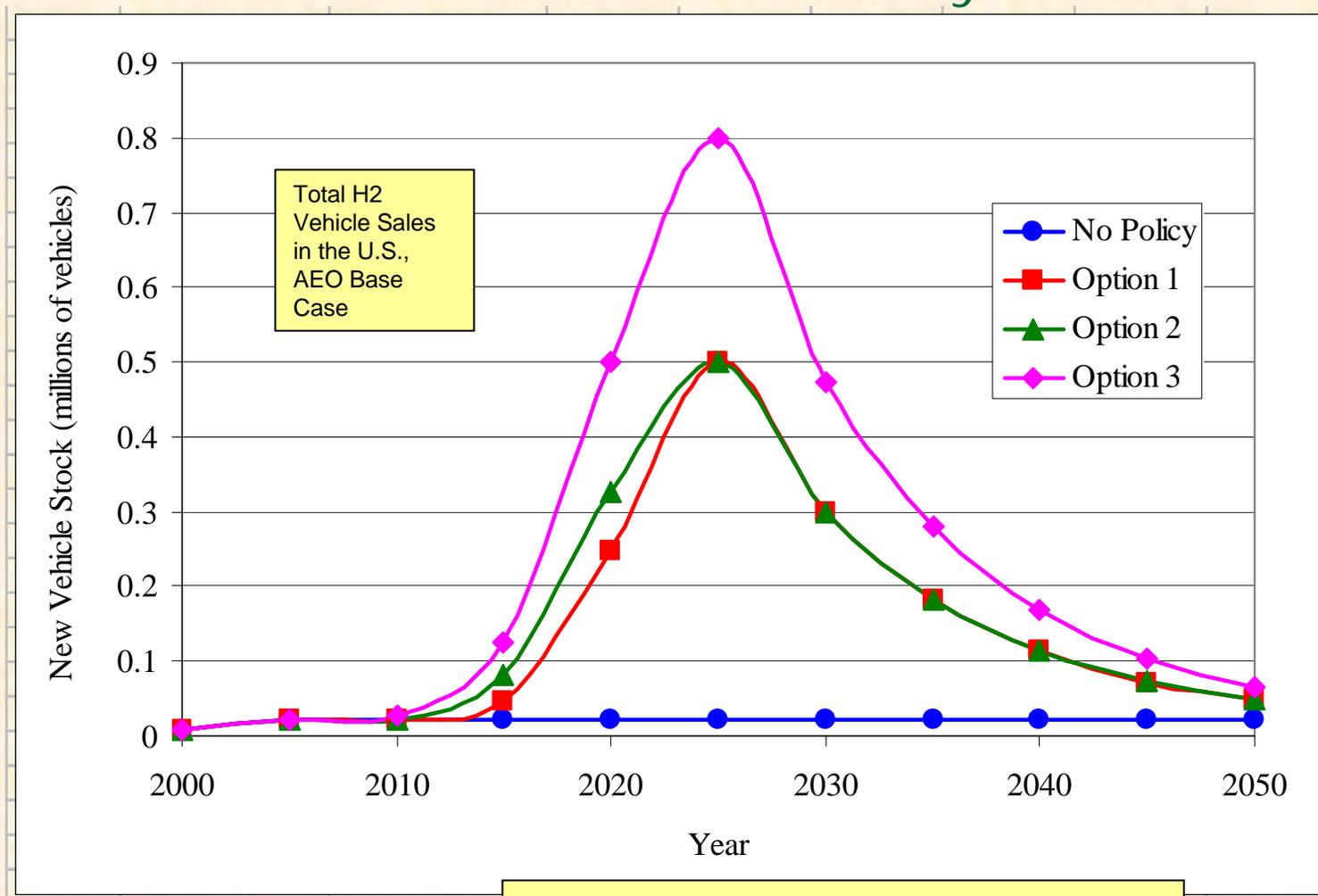
- **Create integrated, market scenarios of the early transition (buy-down, fleet-based).**
- **Develop policy scenarios that evolve to sustainable private sector adoption.**
- **Integrate HyTrans spatially aggregated scenarios with NREL's geographically detailed analyses to create credible, realistic descriptions of the transition to hydrogen-powered vehicles.**
- **Link to and maintain currency with the Delivery, H2A and other analysis team outputs.**

To date we have only executed test runs of the penetrations scenarios to identify the key components of HyTrans needing enhancement.

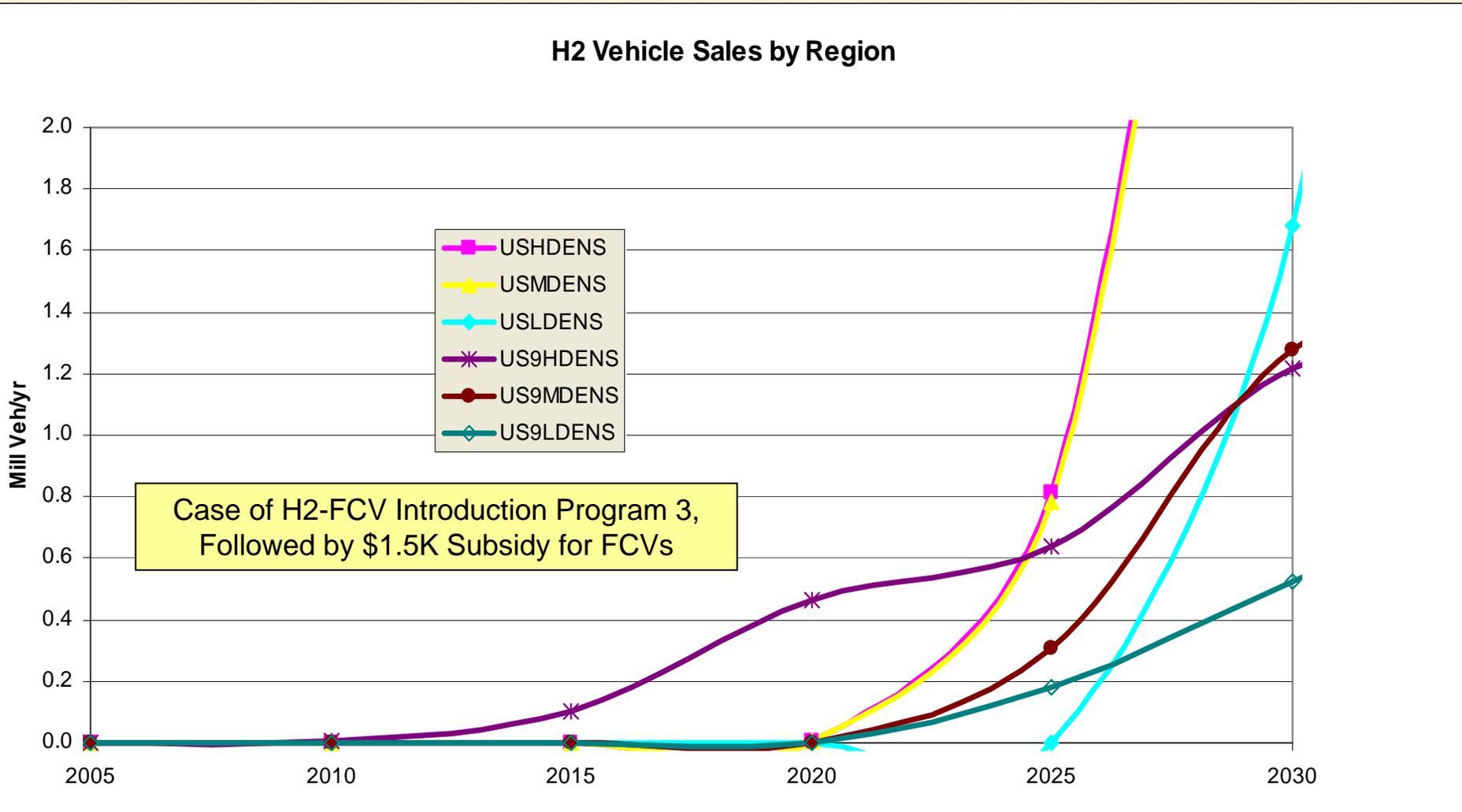
Government Support - Program Options (in thousands of vehicles)															
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Option 1				5	5	5	60	60	100	200	200	240	500	500	1.8M
Option 2				5	5	5	200	200	300	400	500	500	600	700	3.4M
Option 3	5	5	5	60	60	60	200	300	400	500	600	700	1000	1100	5.0M
Option 4	5	5	5	60	100	150	300	500	750	1000	1200	1500	2000	2500	10.0M

These scenarios are provided for transition analyses as recommended by the National Research Council to evaluate the transition phase and do not represent any specific policy recommendation

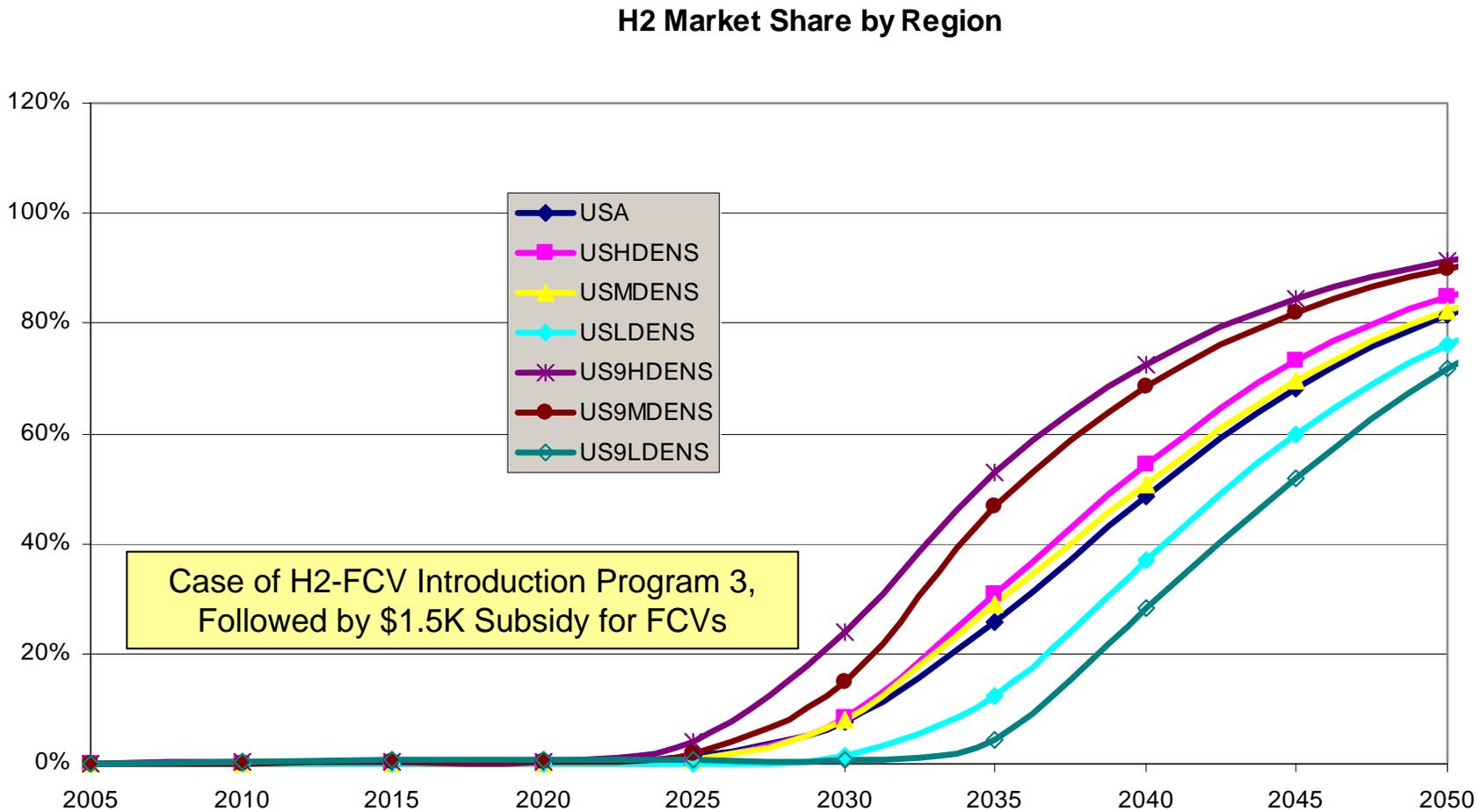
Only mandating that the penetration scenarios target be met, the test runs predict a reversion to conventional ICEs and hybrids.



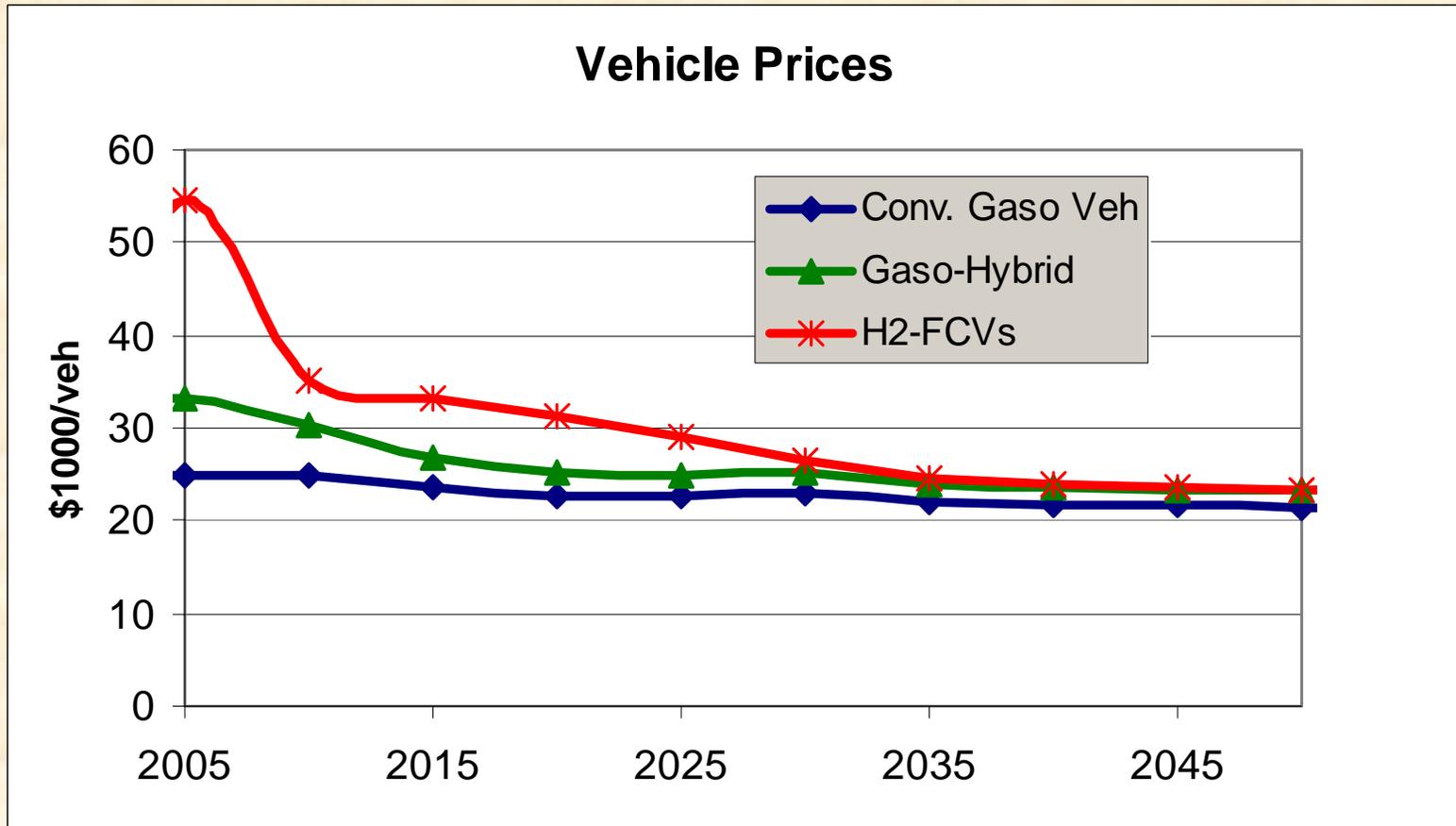
But if we add a subsidy after 2025, H2 vehicle sales take off. (HyTrans put all the penetration scenario vehicle in region 9.)



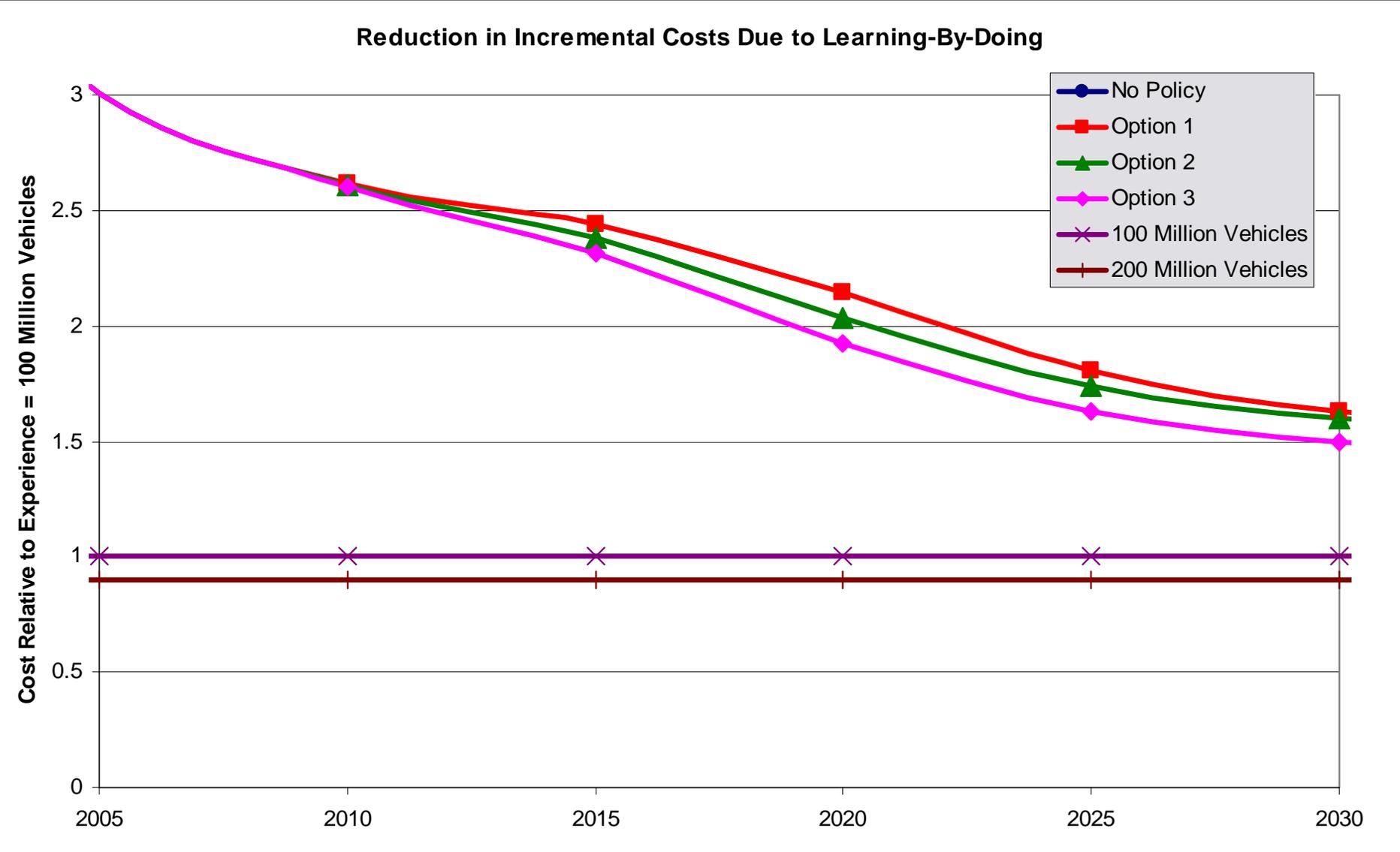
Beyond 2025, H2 vehicle market penetration starts in highest density area of Region 9, and spreads to medium density R9, then rest of USA.



H2 vehicle prices decline quickly due to technological progress, scale economies and learning-by-doing, eventually reaching near parity.



Significant cost reductions via by learning-by-doing are achieved in all the scenarios.



3. What enhancements are needed to realistically model early transitions?

Realistic modeling of the early transition requires enhancements to HyTrans.

- **Added representation of region 9 and rest of U.S.**
- **Added representation of supply from existing H2 production facilities.**
- **More regions & metropolitan areas**
- **Improve representation of existing H2 supply extended to all U.S.**
- **Improve representation of manufacturers' decision making, introduction of makes & models**
- **Improve representation of fuel availability**
- **Link to and establish consistency with NREL detailed GIS analysis**

Diversity of choice among makes and models is a key issue.

- **In NMNL model it is a substantial source of value for consumers.**
- **Diversity value represented by log of ratio of number of makes and models to reference number for conventional technology**
- **Initially, a strong trade-off with scale economies.**
- **Fuel cell vehicle drive train diversity and scale economies may be very different.**

Other improvements to HyTrans will be made in 2006.

- **Regional feedstock supply and transportation demand**
- **Complete and update DOE hydrogen delivery and H2A production models**
- **Enhanced representation of fuel availability**
- **Enhanced representation of consumer choice**
- **Improved scenarios of technological progress**
- **Incorporating alternatives to complete information (“perfect foresight”)**
- **Update calibration to AEO 2006**

4. How will we interface with NREL's detailed GIS analyses?

- **Frequent communication:**
 - 1. Existing H2 production
 - 2. Incorporating the DOE Delivery Model
- **Modeling consistency**
 - Assumptions
 - Processes and their costs
- **Scenario consistency**
 - HyTrans & aggregated NREL correspond
 - NREL provides specifics, geographic detail
 - HyTrans provides integrated market evolution

Thank You.